PCT/EP2004/013962

08.12.2004

REC'D 06 JAN 2005

WIPO PCT

PA 1245010

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

November 05, 2004

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: *60/527,301*
FILING DATE: *December 08, 2003*

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

M. Sias

M. SIAS
Certifying Officer

13281 U.S.PTO

Atty. Dkt. No. 023413-0104

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

15535 U.S.PTO
60/527301
120803

Applicant: Andrew SHORT

Title: METHOD OF PRODUCING A FIBROUS PREFORM

Appl. No.: Unassigned

Filing Date: December 8, 2003

Examiner: Unassigned

Art Unit: Unassigned

PROVISIONAL PATENT APPLICATION TRANSMITTAL

Mail Stop PROVISIONAL PATENT APPLICATION
Commissioner for Patents
PO Box 1450
Alexandria, Virginia 22313-1450

Sir:

Transmitted herewith for filing under 37 C.F.R. § 1.53(c) is the provisional patent application of:

Andrew SHORT
612 Rosemont
Park Hills, KY 41011

Enclosed are:

[X] Specification and Claim(s) (10 pages).

[X] Informal drawings (5 sheets, Figures 1-6).

[X] Application Data Sheet (37 CFR 1.76) (3 pages).

002.1116774.1

Atty. Dkt. No. 023413-0104

The filing fee is calculated below:

			Rate		Fee Totals
Basic Fee			$160.00		$160.00
			SUBTOTAL:	=	$160.00
[ ]	Small Entity Fees Apply (subtract ½ of above):			=	$0.00
			TOTAL FILING FEE:	=	$160.00

[X] A check in the amount of $160.00 to cover the filing fee is enclosed.

[ ] The required filing fees are not enclosed but will be submitted in response to the Notice to File Missing Parts of Application.

[ ] Further, Applicant, by and through his attorney of record, hereby expressly abandons the application as of the filing date of this letter. This is an abandonment of the application only, and is not to be construed as an abandonment of the invention disclosed in the application. It is respectfully requested that the Office acknowledge abandonment of the application as of the filing date of this letter in a communication mailed to the undersigned.

[X] The Commissioner is hereby authorized to charge any additional fees which may be required regarding this application under 37 C.F.R. §§ 1.16-1.17, or credit any overpayment, to Deposit Account No. 19-0741. Should no proper payment be enclosed herewith, as by a check being in the wrong amount, unsigned, post-dated, otherwise improper or informal or even entirely missing, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 19-0741.

Please direct all correspondence to the undersigned attorney or agent at the address indicated below.

Respectfully submitted,

Date 8 December 2003

By George E Quillin

George E. Quillin
Attorney for Applicant
Registration No. 32,792

FOLEY & LARDNER
Washington Harbour
3000 K Street, N.W., Suite 500
Washington, D.C. 20007-5143
Telephone: (202) 672-5413
Facsimile: (202) 672-5399

METHOD OF PRODUCING A FIBROUS PREFORM

The invention relates to a process for fabricating a near-net shape preform for use in a composite brake disc. While the preform is particularly suited for use in a carbon/carbon composite, it may also find use in other composite applications that use ceramic, polymeric, or metal matrices. The preform is a thick, porous, three-dimensional structure that is composed entirely of carbonized fiber and/or carbonized fiber precursors.

Carbon fiber has been widely used in the fabrication of composite materials. The two most commonly used types of carbon fiber are pitch-based and PAN-based carbon fiber. The two fibers have different properties and advantages/disadvantages, depending on their intended use. For example, U.S. Patent No. 5,705,008 (Hecht) makes a strong point regarding the advantages of using thermoset pitch fiber in a carbon preform, such that Hecht claims exclusively pitch fiber. For the purposes of this invention, both PAN-based, pitch-based, and a combination of PAN-based and pitch-based carbon fibers are suitable and within the scope of the present invention. Commercial examples of PAN-based carbon fiber include, but are not limited to, PANEX 35 (produced by Zoltek Corporation), THORNEL T-300 (produced by Cytec Engineered Materials), and SIGRAFIL C (produced by SGL Carbon Group). An example of pitch-based carbon fiber includes, but is not limited to, pre-carbonized THORNEL P-25 (produced by Cytec Engineered Materials but typically commercially available only in a post-carbonized state).

The carbon fiber may be used in various forms, such as chopped fiber, non-woven fabric, continuous filament, etc. It is understood that many different types of fiber arrangements may be employed within the scope of the present invention. As such, the term "preform material" will be used from this point forward to refer to the fiber arrangement employed in the preform design.

Since traditional textile material is produced in sheet, or rectangular, form, using such material to produce a circular-shaped preform is problematic. A circle or annulus must be cut out of the rectangular material, generating significant waste. The following patents relate to processes for producing an annular, near-net shape preform with the goal being to reduce the fiber waste that normally accompanies this type of

process: U.S. Patent No. 5,705,008 to Hecht; U.S. Patent No. 5,686,117 to Sndyer, et al.; U.S. Patent No. 6,083,436 to Thompson, et al.; U.S. Patent No. 5,952,075 to Clarke, et al.; U.S. Patent No. 5,662,855 to Liew, et al.; U.S. Patent No. 5,546,880 to Ronyak, et al.; and U.S. Patent No. 5,113,568 to Lawton, et al.

Traditional processes can be grouped into three broad categories: (1) Producing a spiral fabric (braid, weave, knit) that is laid down into an annulus, (2) Cutting arcuate or trapezoidal sectors of an annular shape from a textile sheet and then assembling these sections into the preform, and (3) Dispensing fiber (chopped or continuous) into an annular mold.

Method (1) involves the costly and time-consuming step of producing a fabric. In addition, to compensate for a fiber volume gradient from inner to outer diameter in the fabric, complicated techniques must be employed that further increase the required production time. Method (2) still produces considerable off-cut waste, as well as requiring the extra steps of cutting and assembling the sectors. Method (3), while eliminating many of the drawbacks of the previous two methods, still contains process deficiencies that are addressed by the present invention.

As previously stated, traditional processes in the third category use hollow, annular molds to hold the fiber. The continuous or chopped fiber is fed into the mold and subsequently bonded together, either through a carbonizable resin or through needlepunching. In some instances, a binder agent is applied to hold the fibers together. The needling operation is accomplished by rotating the perform material (either in the mold or out of the mold) under a reciprocating needle head in an annular needle loom until the desired needling density is accomplished. This approach has several drawbacks. First, the use of a binder agent adds additional cost to the process, as well as placing impurities into the preform. Second, the process of rotating the perform material under the needling head leads to a phenomenon known as "tracking." Tracking refers to a situation in which the same points on the preform are needled repeatedly, resulting in a distinct, often visible needling pattern. Tracking is not desirable because it produces non-uniformity within the preform. As the same areas are needled repeatedly, the z-fiber content (fibers oriented in the z-direction) in those areas becomes disproportionably large compared to the surrounding areas. Localized

concentrations of z-fiber can produce in-plane vs. out-of-plane thermal and stress gradients that are detrimental in a composite material. Third, traditional processes require the production of only one preform at a time on the needle loom. The present invention does not require a binder, avoids the tracking problem, and makes use of a conventional linear needle loom to increase production throughput.

According to an embodiment of the present invention, Figure 1 shows a top plan view of a mold plate 1 used to contain the preform material. Figure 2 shows a side cross-sectional view of the mold plate 1 of Figure 1.

The mold plate 1 is made of any suitable material that allows sufficient needle penetration without damaging the needles and is also durable enough to withstand multiple production cycles. Examples include, but are not limited to, a 3-D textile mold, cellular foam, neoprene foam, and Styrofoam. The mold plate 1 comprises an outer portion 2, which includes a series of mold cavities 3 into which the perform material is placed. The mold cavities 3 are disc-shaped holes that can be cut into the outer portion 2 with a traditional cutting die. The mold plate 1 further comprises cylindrical cores 4. A core 4 is disposed within each mold cavity 3 at the center of the mold cavity 3. As part of the mold plate 1, the cores 4 are also made of any suitable material that allows sufficient needle penetration without damaging the needles and is also durable enough to withstand multiple production cycles. The dimensions of the mold plate 1 can be varied according to the application for which the mold plate 1 is being used. For example, according to an embodiment of the present invention, the approximate dimensions of the mold plate 1 are 55 mm high by 600 mm wide by 11 m long. In particular, the length of the mold plate may vary greatly depending on the process used to produce the fibrous preform.

The mold plate 1 may optionally include a support surface, which retains the preform material in the mold cavities 3 while at the same time allowing for efficient needle penetration into the preform material. According to one embodiment of the present invention, the support surface comprises supports 5. Figure 3a shows a top plan view of a support 5. The supports 5 can be, for example, thin, disc-shaped members with an outer diameter approximately equal to the outer diameter of the mold cavities 3 and an inner diameter approximately equal to the outer diameter of the cores 4. As

with the mold plate 1, the supports 5 are made of any suitable material that allows sufficient needle penetration without damaging the needles and is also durable enough to withstand multiple production cycles. A support 5 is disposed within a mold cavity 3 so that an outer face of the support 5 is substantially flush with an outer face of the mold plate 1. Figure 3b shows a cross-sectional view of a mold plate 1 with supports 5 disposed within the mold cavities 3. The supports 5 can be placed into the mold cavities 3 after the cores 4 are positioned in the mold cavities 3. Alternatively, the supports 5 can be integrally formed with the mold plate 1.

According to another embodiment of the present invention (not shown), the support surface may be composed of, for example, a very thin, lightweight fabric (often referred to as scrim fabric). Such a support surface may be used, for example, with a needlepunching operation that includes needling from two faces of the mold plate 1. For example, a needling operation may include needling from one face of the mold plate 1 and needling from the opposite face of the mold plate 1. According to one embodiment of the present invention, needlepunching from two faces can be accomplished by needling one face of the mold plate 1 (e.g., the face of the mold plate 1 facing upward), flipping the mold plate 1 180 degrees, and then needling the opposite face. According to another embodiment of the present invention, needlepunching from two faces can be accomplished by needling one face and needling the opposite face without flipping the mold plate 1. In a case where the mold plate 1 is not flipped, the fabric support surface described above can be used to retain the preform material in the mold cavities 3 when the downward-facing face of the mold plate 1 is needlepunched.

Prior to placing the perform material into the mold cavities 3, the cores 4 are positioned within the mold cavities 3. According to an embodiment of the present invention, a template 6 can be used to position the cores 4 in the center of the mold cavities 3 to ensure that a core 4 is concentric with the outer edge of a mold cavity 3. Figure 4a shows a top plan view of a template 6. The template 6 can be composed of any suitably rigid material, for example, a metallic material. The template 6 includes an outer ring 7, which has an outer diameter that corresponds to the outer diameter of the mold cavities 3. The template 6 also includes a center ring 8, which has an inner diameter that corresponds to the outer diameter of the cores 4. The template 6 further

includes spokes 9, which connect the outer ring 7 and the center ring 8 and which position the center ring 8 concentrically with the outer ring 7. The spokes 9 can be, for example, metal bars. The template 6 can be placed into the mold cavity 3 (for example, by an operator or an automated machine). Figure 4b shows an exploded perspective view of a template 6 and a portion of the mold plate 1. Once the template 6 is in place within the mold cavity 3, a core 4 is positioned within the center ring 8. The template 6 is then removed, leaving the core 4 properly positioned within the mold cavity 3. If desired, a support 5 can next be placed into the mold cavity 3, as discussed above. The mold cavities 3 are now ready to receive preform material.

The preform material is arranged appropriately within each mold cavity 3 according to any known method. Once the preform material is in place, the perform material is needlepunched using a conventional linear needle loom in order to reorient some fibers in the z-direction, thus imparting dimensional stability to the perform, as well as imparting the desired out-of-plane (z-axis) composite properties. According to an embodiment of the present invention, the needlepunching occurs in two steps. First, the perform material is needled from the top, followed by needling from the opposite face. It is understood that the two needling steps can be integrated into one machine or can be accomplished with two separate needle looms. For example, if it is desired to use only one machine, a needle loom that needles from two directions can be used, or a needle loom that needles from one direction can be used and after the first face is needled, the mold plate 1 can be flipped over so that the second face can be needled. Needling from both faces serves to improve the uniformity of the z-fiber distribution through the thickness of the preform.

The needle loom employed in the present invention is a conventional linear needle loom. In order to avoid tracking, the needle board is sized appropriately to maintain a random punch pattern while still imparting the necessary needling density. This may be achieved by using a large needle board (for example, > 300 mm in the processing direction) or by using multiple needle boards. According to an embodiment of the present invention, as shown in Figure 5, the mold plate(s) are advanced at the desired speed underneath the needle board, so that the process is more or less continuous, limited only by the length of the mold plate. The combination of advance

speed and needle stroke speed can be adjusted as desired in order to achieve a wide range of needling densities. The "tracking" inherent in the traditional processes is avoided by allowing the mold plate(s) to have freedom of movement in the lateral (non-machine) direction. This movement can be enhanced by employing a mechanism that imparts slight lateral movements to the mold plate as it travels under the needle board.

In the present invention, the needle loom is preferably sized to process multiple mold plates in parallel in order to increase the productivity of the system. As shown in Figure 6, the mold plates 1 can, for example, lie side by side as they advance through the needle loom in the machine direction. The mold plates 1 could also be arranged one after the other (not shown). This aspect of the present invention provides a greater industrial throughput over the traditional processes where a single preform is rotated under an annular needle loom.

It is known to those skilled in the art that during a traditional needlepunching operation, the majority of the z-fiber that is transferred by each needle is taken from the upper portion of the preform. For example, on a common needle that has nine barbs, the first three barbs carry 60% of the total z-fiber transferred by that needle. As the needle penetrates the perform material, the barbs are fully loaded with fiber after the first few millimeters of penetration. With a constant penetration depth, there will be a z-fiber gradient through the thickness of the preform, with the center of the preform having less z-fiber than the outer faces. In the past, attempts at uniformity in the z-direction were achieved by slowly lowering the bedplate of the needle loom as the preform thickness was increased layer by layer. Such a process requires more processing time since the preform must be built one layer at a time. The layering process also has the possibility of exhibiting delamination during subsequent processing if the needling is not tightly controlled. In the present invention, desired needle penetration uniformity may be achieved by introducing an angle between the bedplate and the needle board. For example, according to an embodiment of the present invention, the use of an angled bedplate may be employed to accomplish the desired needle penetration uniformity. The bedplate is angled upward, gradually getting closer to the needle board as the mold plate(s) move in the machine direction. When such a design is employed, the perform material will first encounter the needles

at the low end of the bedplate, resulting in a relatively low penetration depth. As the leading edge of the mold plate (and the perform material) progresses under the needle board, the slope of the bedplate serves to bring the material closer to the needle board, effectively increasing the penetration depth.

The preform material, once needled, may be carbonized to achieve further fiber purity and desired physical properties. The preform is then densified using any acceptable densification method, such as chemical vapor infiltration, to achieve final composite density. The introduction of a matrix during densification increases the density of the preform. A final heat treatment may also be employed to achieve the desired final composite properties.

WHAT IS CLAIMED IS:

1. A method of producing a fibrous preform, comprising:

providing a mold plate including fibrous material arranged in a mold cavity, wherein the mold plate is adapted to allow needle penetration by a needle loom;

advancing the mold plate through the needle loom;

moving the mold plate in a direction transverse to a direction of advancement of the mold plate; and

needlepunching the fibrous material to mechanically reorient a portion of the fibrous material.

2. The method of claim 1, wherein the fibrous material comprises discontinuous PAN fiber.

3. The method of claim 1, wherein the fibrous material comprises discontinuous pitch fiber.

4. The method of claim 1, wherein the fibrous material comprises discontinuous PAN fiber and discontinuous pitch fiber.

5. The method of claim 1, wherein the needle loom comprises a linear needle loom.

6. The method of claim 1, wherein the needlepunching comprises needlepunching a top portion of the fibrous material and needlepunching a bottom portion of the fibrous material.

7. The method of claim 1, further comprising needlepunching the fibrous material with a second needle loom.

8. The method of claim 1, wherein the step of advancing the mold plate through the needle loom and the step of moving the mold plate in a direction transverse to a direction of advancement of the mold plate occur simultaneously.

9. The method of claim 1, wherein the step of providing a mold plate includes providing a plurality of mold plates disposed side by side.

10. The method of claim 1, further comprising angling the mold plate in an upward direction as the mold plate advances through the needle loom.

11. The method of claim 1, further comprising producing a near-net shape fibrous preform adapted to be used for manufacturing carbon/carbon brake discs.

12. The method of claim 1, further comprising carbonizing the fibrous material.

13. The method of claim 1, further comprising densifying the fibrous material.

14. The method of claim 13, further comprising heat treating the fibrous material.

15. A method of producing a fibrous preform, comprising:

providing a mold plate adapted to allow needle penetration by a needle loom, wherein the mold plate includes a cavity portion and a core portion, and wherein the core portion is adapted to be disposed within the cavity portion;

providing a template adapted to be removeably disposed within the cavity portion and to enable the core portion to be positioned concentrically with the cavity portion;

placing the template into the cavity portion;

positioning the core portion within the cavity portion using the template; and

removing the template.

16. The method of claim 15, further comprising placing a support within the cavity portion, wherein the support is adapted to be disposed within the cavity portion such that an outer face of the support is substantially flush with an outer face of the mold plate.

17. The method of claim 15, further comprising arranging fibrous material within the cavity portion.

18. The method of claim 17, further comprising:

advancing the mold plate through the needle loom;

moving the mold plate in a direction transverse to a direction of advancement of the mold plate; and

needlepunching the fibrous material to mechanically reorient a portion of the fibrous material.

Figure 1

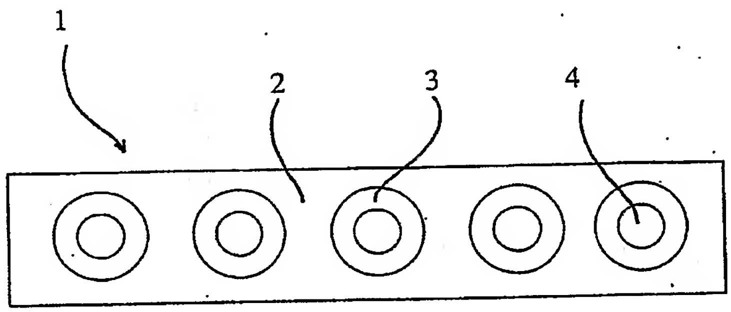
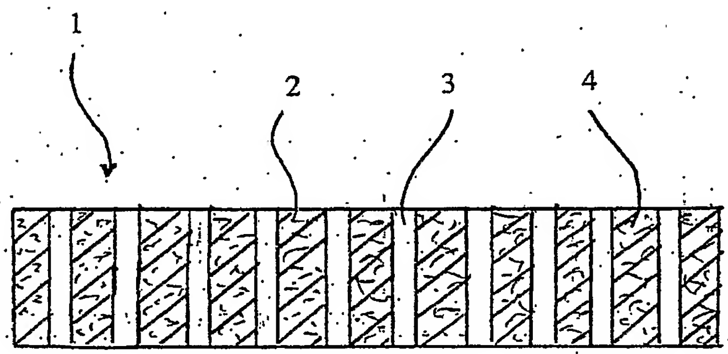


Figure 2



TITLE: Method of Producing a Fibrous Preform
INVENTOR: A. SHORT
Attorney Docket No.: 023413/0104

Figure 3a

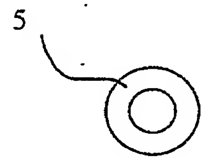
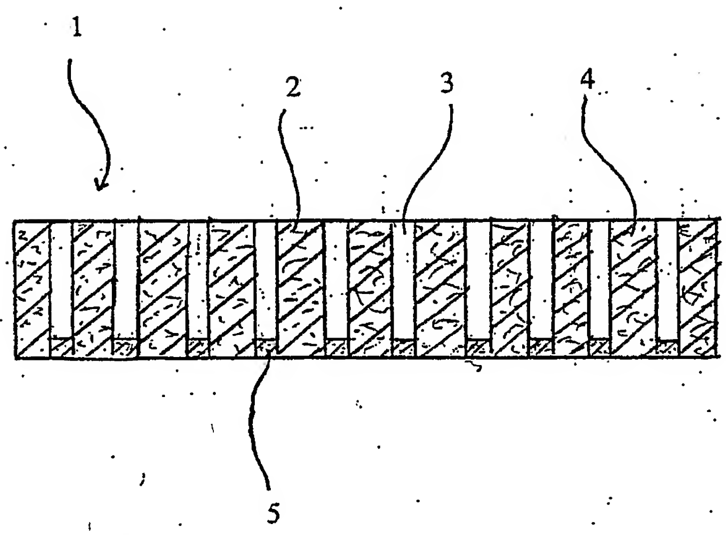


Figure 3b



TITLE: Method of Producing a Fibrous Preform
INVENTOR: A. SHORT
Attorney Docket No.: 023413/0104

Figure 4a

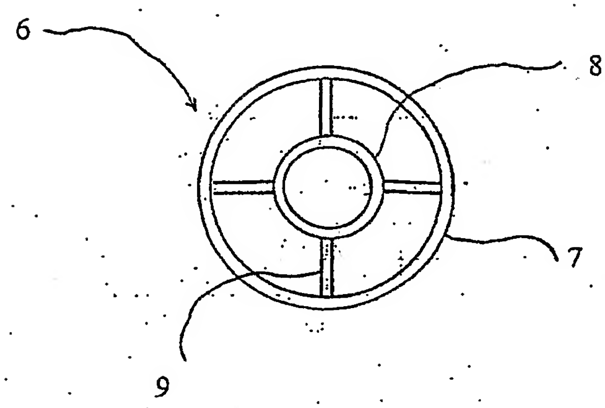
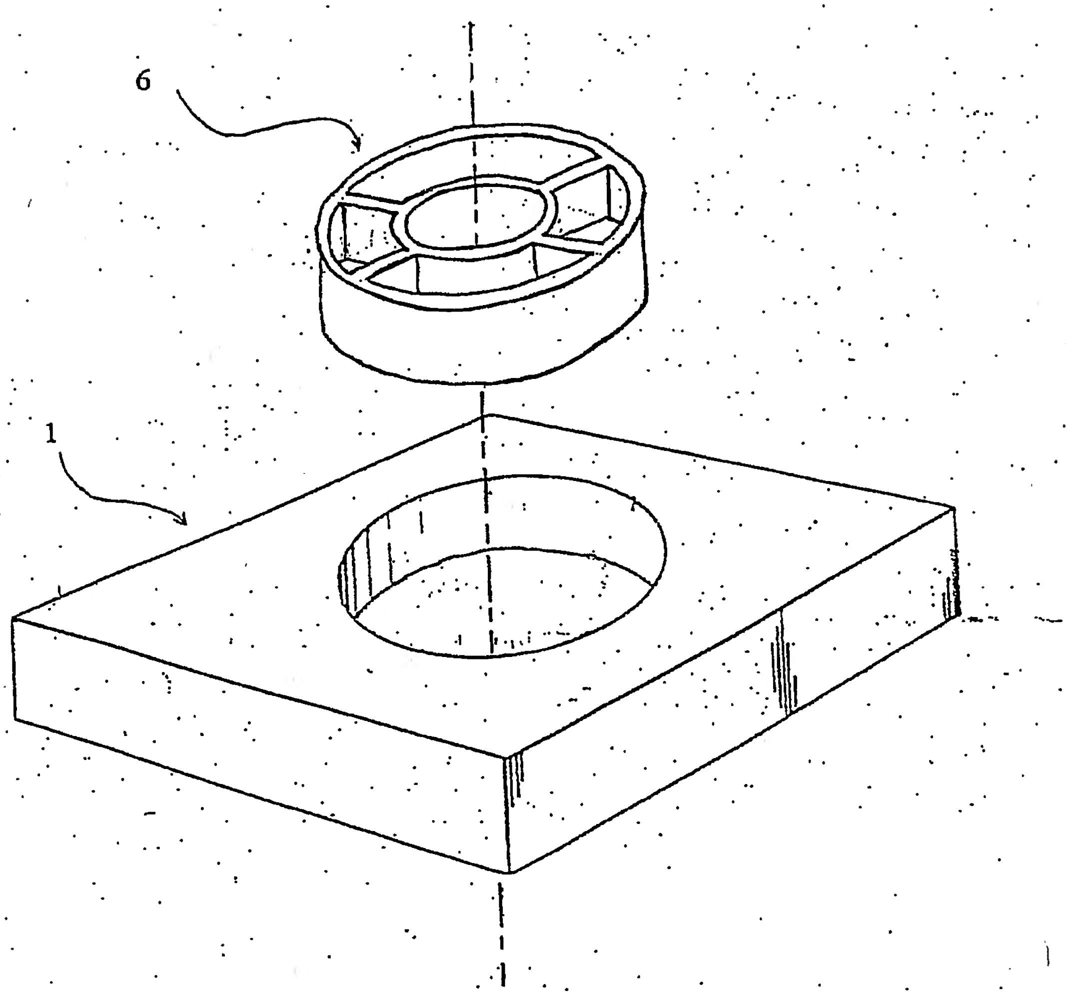


Figure 4b



TITLE: Method of Producing a Fibrous Preform
INVENTOR: A. SHORT
Attorney Docket No.: 023413/0104

Figure 5

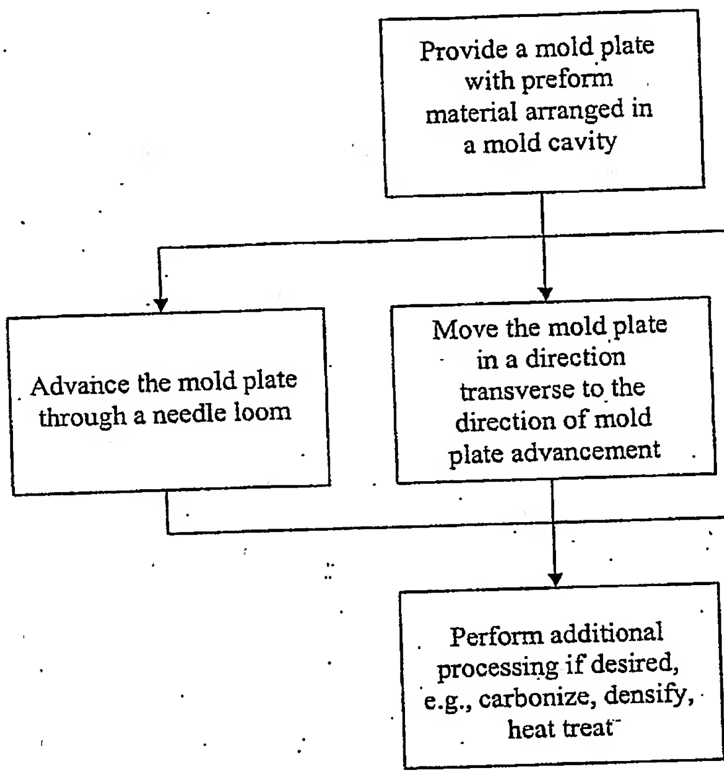


Figure 6